



SUBSEA INSPECTION AND SENSINGS TECHNOLOGY CLEAR GULF JIP

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Astro Technology Inc.

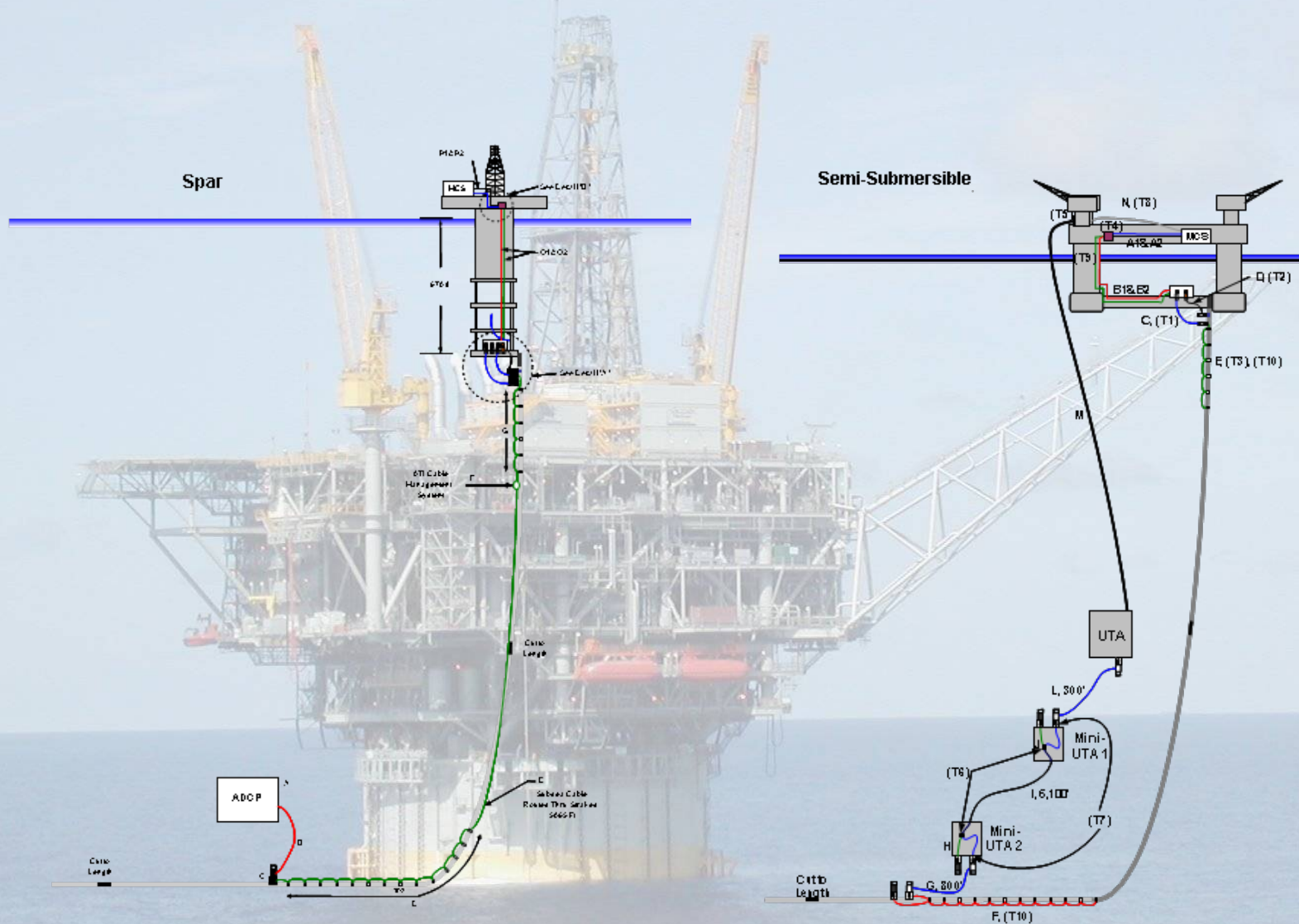
October 21, 2010

CLEAR GULF JOINT INDUSTRY PROJECT

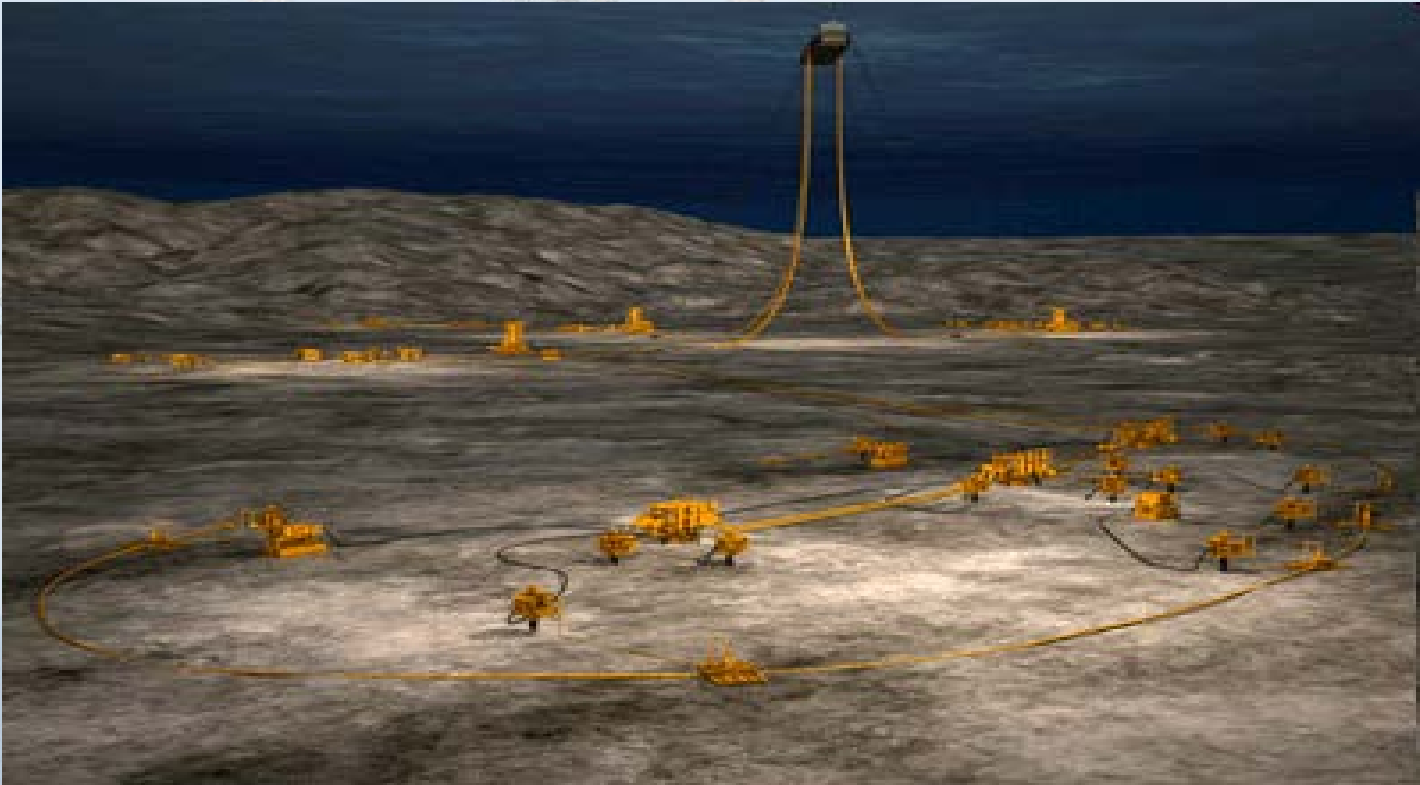
- JIP Formed in 2010
 - Joint project involving NASA, Oil and Gas companies and Astro Technology
- Advances Sensing/Inspection Technology in Deepwater Fields for Oil and Gas Exploration and Production

CLEAR GULF JIP OVERVIEW

- Advance existing sensing technology
 - Measurements to mitigate structural failure
 - Strain, vibration, fatigue
 - Flow assurance – problem identification
 - Temperature, pressure, wax build-up, hydrate formation
 - Leak detection
 - Subsea field inspections



SUBSEA TECHNOLOGY OVERVIEW



CLEAR GULF JIP ADVANTAGES

- Reduce risk of hydrocarbon spillage
- Improve safety
- Significant cost avoidance and downtime
- Assists in regulatory compliance
- Improved subsea field design
- Low investment cost for JIP participants
- Utilize NASA facilities and expertise
 - US flagship technology organization
- Credible third party involvement

EXPECTED JIP OUTCOME

- Improvement to operation methods in oil and gas projects
- Enhanced safety for offshore operations
- Better environmental control and reduction in leak potential
- Industry wide job creation

ADDITIONAL JIP NEEDS

- Cost effective methods to deploy sensors in subsea environment
 - Mini-Remote Operated Vehicle (ROV)
 - Subsea robotic manipulators and interfaces
 - ROV communications to topside
 - Additional subsea sensor types

Offshore Projects

- Bass Lite
- Devils Tower
- Geauxpher
- Troika
- Pluto
- BP Ocean Clipper / Ocean Confidence
- Mardi Gras
- Holstein
- Thunder Horse
- Brass LNG – Engineering phase

INSTRUMENTATION METHODS

TRIDENT SUBSEA MONITORING SYSTEMS



Monitoring Systems

- Deepest monitoring system – 7500 ft
- Longest monitoring system– 60 miles @ 7000 ft depth
- Coldest – cryogenic LNG and LN2
- Hot – interior of solid rocket motor

Vision for Offshore Monitoring Technology

- Monitoring Systems as a vital input to long term Riser and Pipeline Integrity Management
- Smart Field Technology supporting Flow Assurance of pipeline systems
- Innovative methods implementation

SCOPE OF WORK

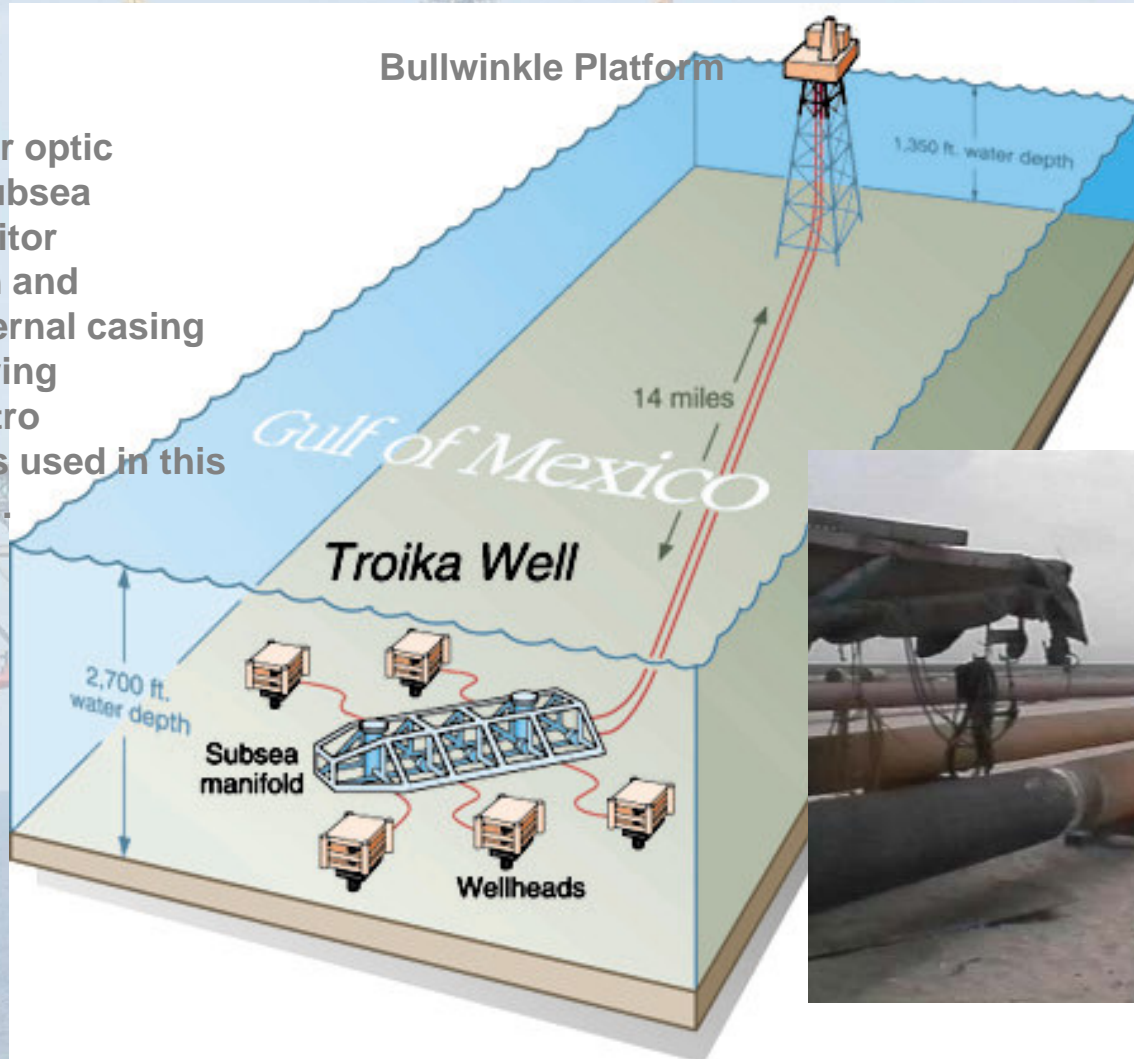
- Temperature, pressure, strain monitoring
- Mitigate structural failure
- Low cost – ease of use inspection system
- Flow assurance
- Hydrate and wax detection
- Slugging – sloshing monitoring
- Leak detection
- Subsea field real time monitoring

SOW - Visual Inspection of Subsea Deepwater Pipelines

- Preliminary study to visually inspect pipeline at depths up to 10,000 feet.
- React to anomalies reported through fiber optic monitoring system.
- Visual data will be analyzed and displayed along with strain, pressure and temperature data.

Troika - Gulf of Mexico

First use of fiber optic sensors on a subsea pipeline to monitor pressure, strain and vibration in external casing pipe bundle during fabrication. Astro Technology was used in this new application.

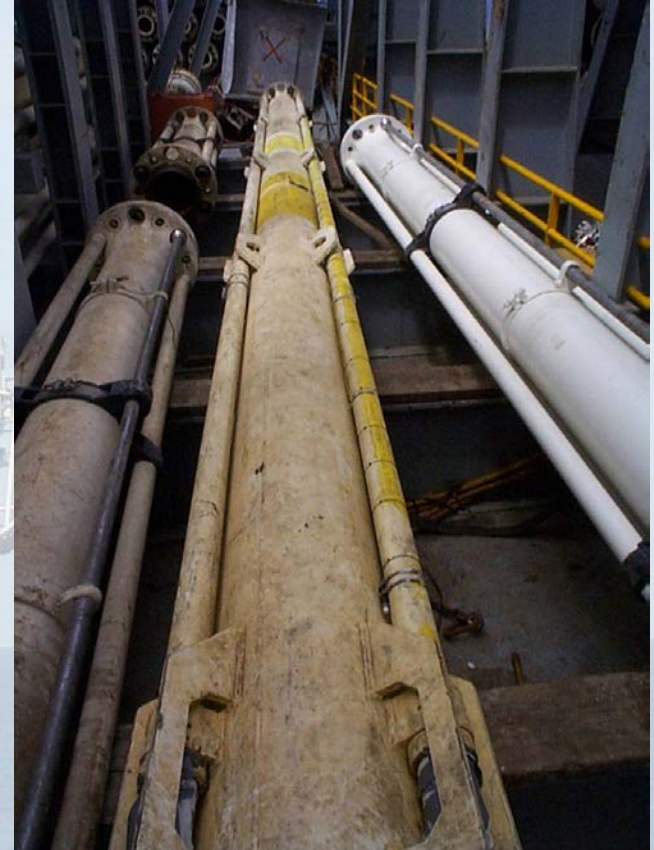




FIBER-OPTIC SENSORS FOR DEEPWATER DRILLING

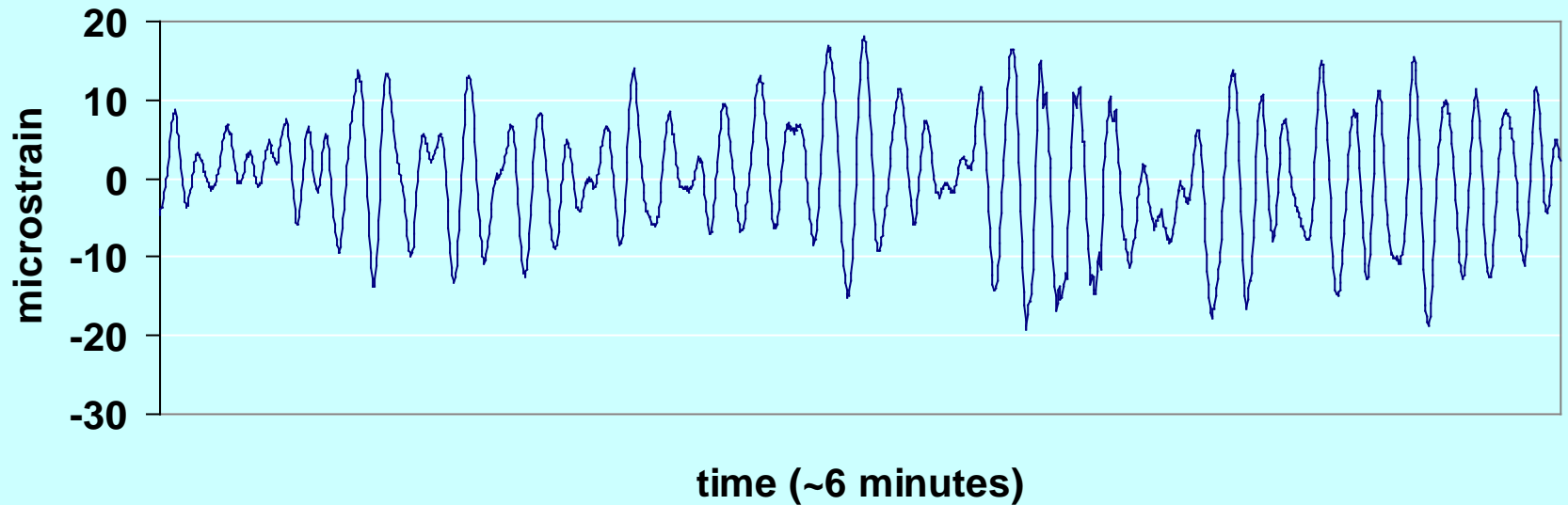


OCEAN CLIPPER



OCEAN CLIPPER VIV DATA

Fiber-optic Sensor Data



FIBER-OPTIC SENSORS FOR DEEPWATER DRILLING

- **Measurement of strain & vortex induced vibration (VIV)**
- **Tool for service life evaluation & time-to-inspection**
- **Concern for structural integrity of drilling risers**
- **Fiber-optic sensors for deepwater drilling operations**
 - Depths up to 12,500 feet – currently 7500 feet
- **Fatigue assessment**
- **Real-time monitoring of strain and vibration**
- **Riser management tool to**
 - Increase service
 - Detect damage

[Show Riser Manager](#)[Current Tank](#)

Bass Lite Real Time Monitoring



FLMT #2 (18 miles)

T 56.55 °F

[Temperature \(°F\) last 24 hrs](#)

[Temperature \(°F\) last month](#)

P 1588.05 psig

[Pressure \(psig\) last 24 hrs](#)

[Pressure \(psig\) last month](#)

FLMT #1 (36 miles)

T 37.06 °F

[Temperature \(°F\) last 24 hrs](#)

[Temperature \(°F\) last month](#)

P 2255.21 psig

[Pressure \(psig\) last 24 hrs](#)

[Pressure \(psig\) last month](#)

FLET (57 miles)

T 27.32 °F

[Temperature \(°F\) last 24 hrs](#)

[Temperature \(°F\) last month](#)

P 2588.79 psig

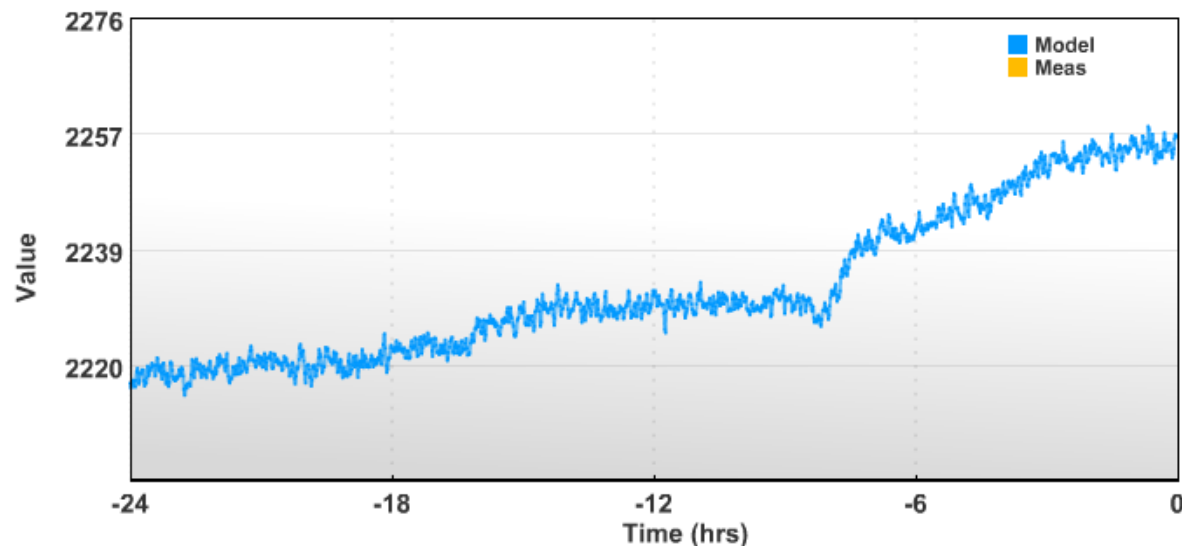
[Pressure \(psig\) last 24 hrs](#)

[Pressure \(psig\) last month](#)



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bass_lite.bl.flmt1.p



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Ruggedization and Reliability Efforts



- **Ruggedization task developed for pipelines/risers**
 - Sensors, connectors, cabling, deployment methods
- **7500-ft deep instrumented systems**
- **9-month deployment in deepwater followed by topside inspection and verification testing**
- **Laboratory testing demonstrated sensor and hardware usage up to 12,500-feet depths**
- **RESULTS: Successfully demonstrated ruggedness and reliability**

Deployment from Ocean Confidence

- Moonpool access to the riser flange



Observations Following Nine-month Deployment

- The fiber-optic sensors were fully functional following 9-months of subsea service
- The sensors were able to accurately measure dynamic strains in the joint
- The Fiberglass/epoxy case used to protect sensors maintained integrity and showed no evidence of degradation
- Subsea connector - fiber-optics in excellent condition

Post Deployment Riser Observations

- Removal of buoyancy modules to inspect sensors and protective Fiberglass/epoxy wrap



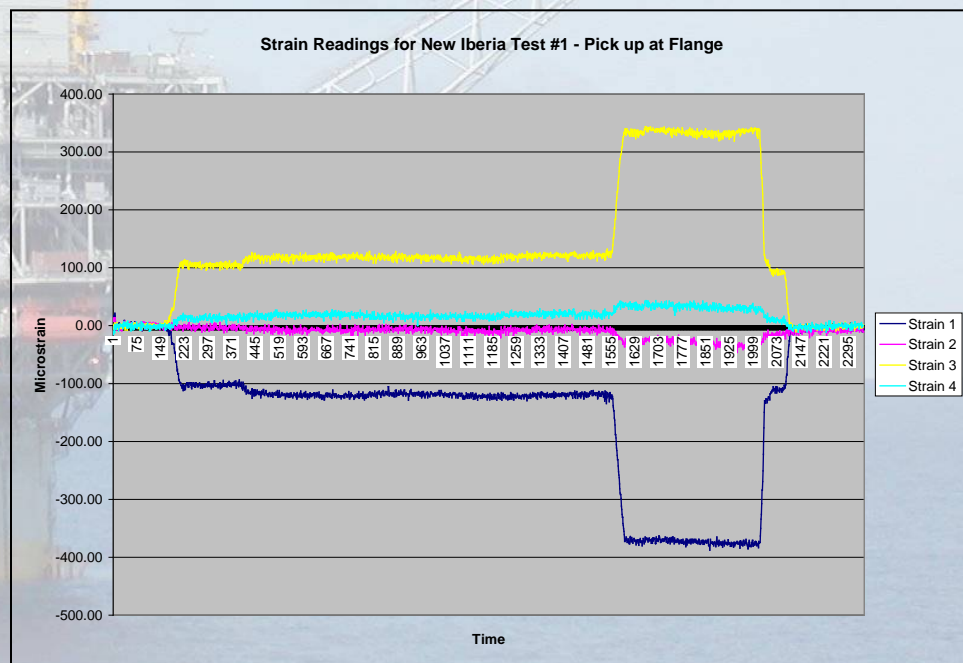
Post Deployment Riser Observations

- Excellent Fiberglass/epoxy condition
- Intact rugged optical cable



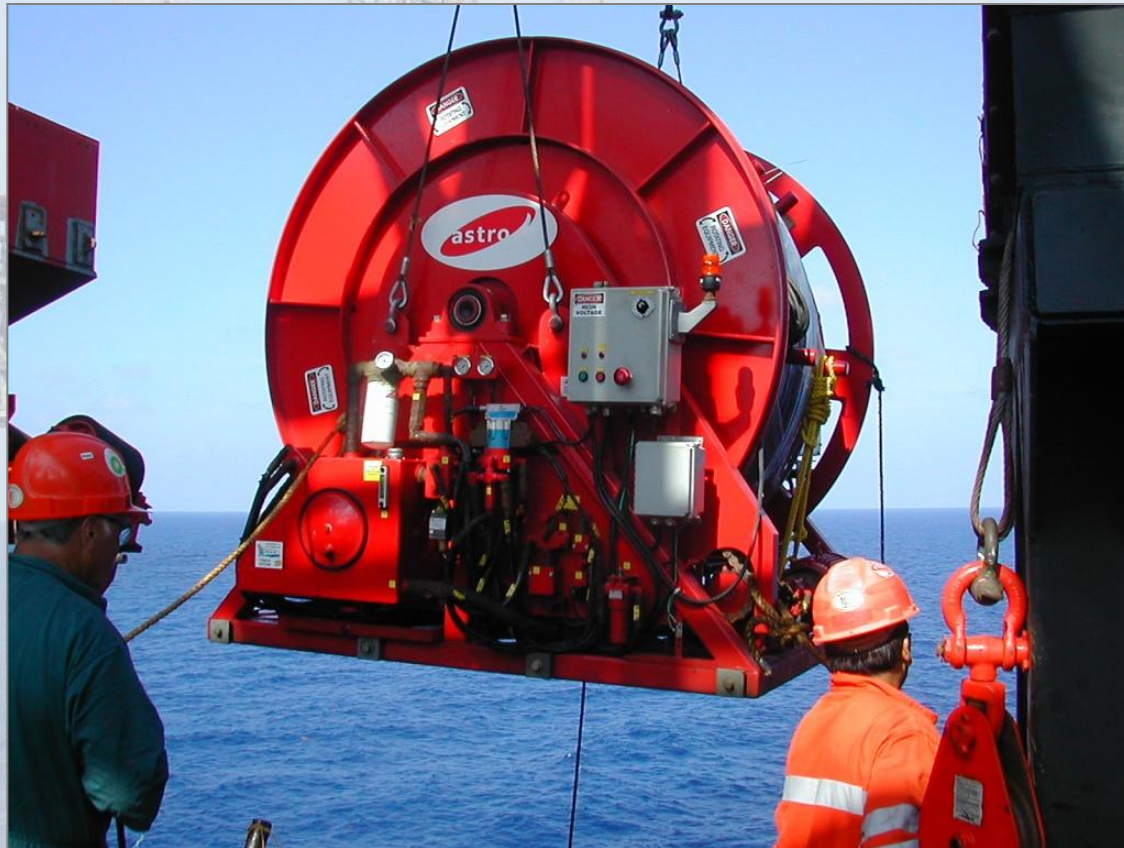
Post Deployment Riser Testing

Data collected when one end of the joint was lifted with a crane



Riser Monitoring System

- Offshore Cable Installation



Riser Monitoring System

- Topside Equipment Rack Installation



SCR Monitoring System

- Offshore Installation



Riser Monitoring System

- Sensor Station Installation



Riser Monitoring System

- SCR Cable Manufacture



Riser Monitoring System

- Hull Conduit Cable Installation



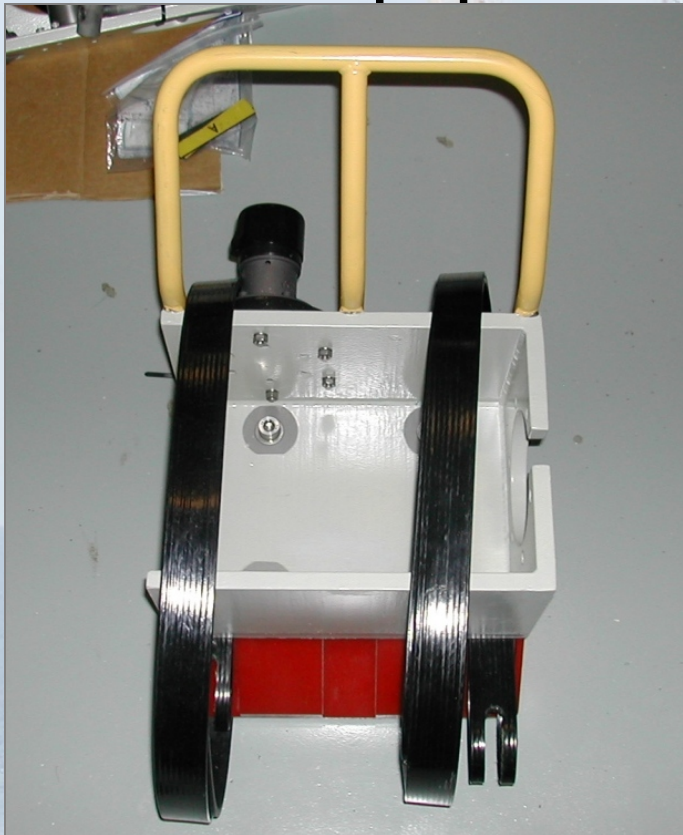
Riser Monitoring System

- Kit Equipment Manufacture



Riser Monitoring System

- Kit Equipment Manufacture



Riser Monitoring System

- Offshore Fiber and Electrical Hookup



Riser Monitoring System

- Offshore Cable Installation



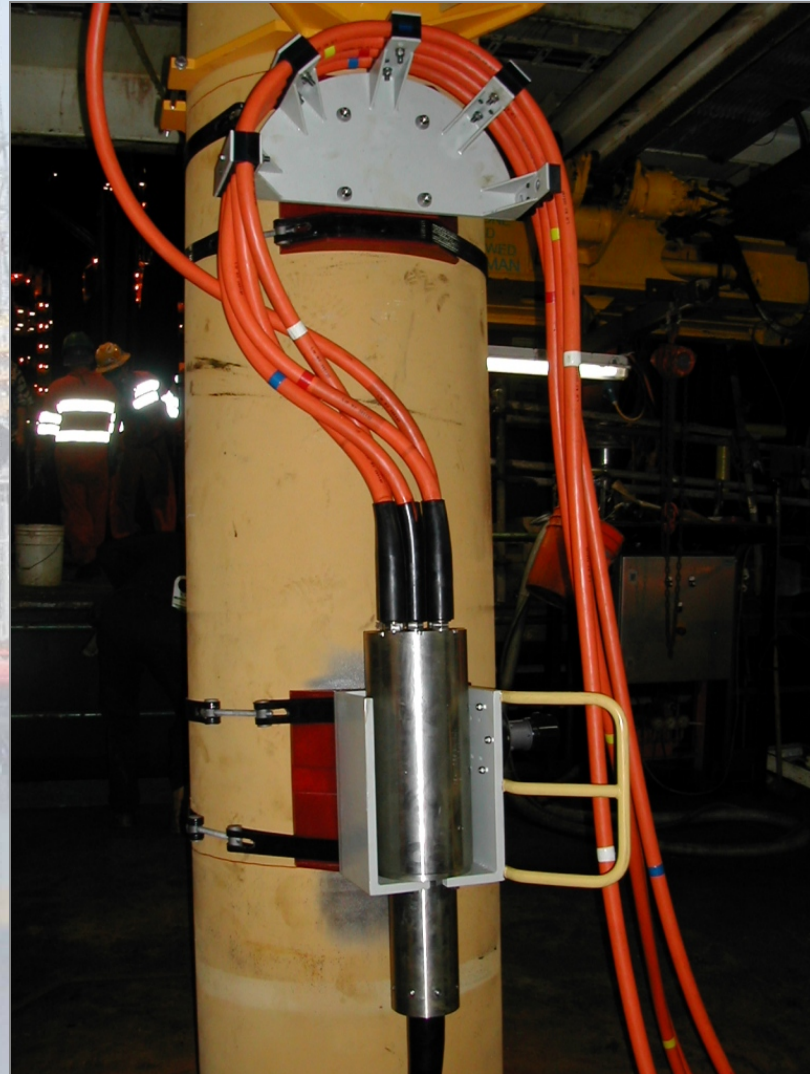
Riser Monitoring System

- Offshore Installation



Riser Monitoring System

- Offshore Cable Installation



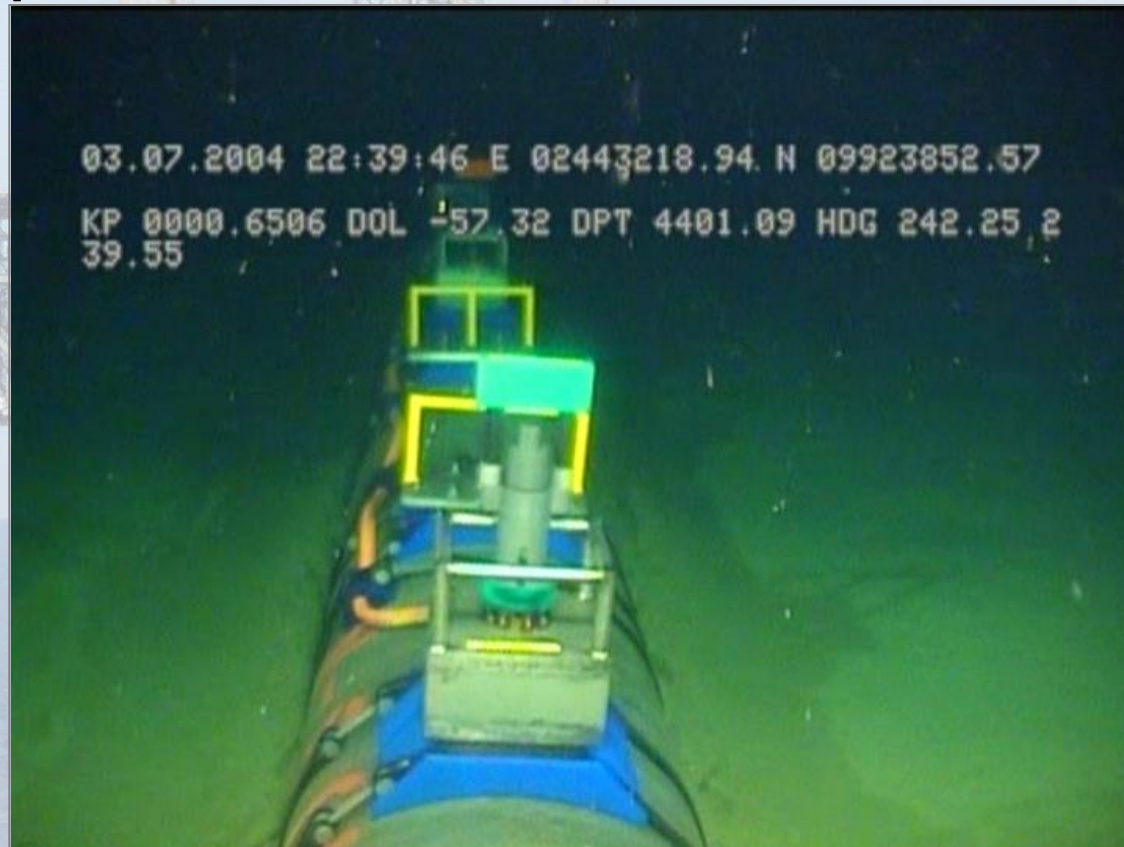
Riser Monitoring System

- Offshore Installation



Riser Monitoring System

- Deepwater Installation



Riser Monitoring System


- Deepwater Installation



03.07.2004 22:53:38 E 02442843.97 N 09923576.81
KP 0000.1865 DOL -22.15 DPT 4378.28 HDG 237.75 2
39.55

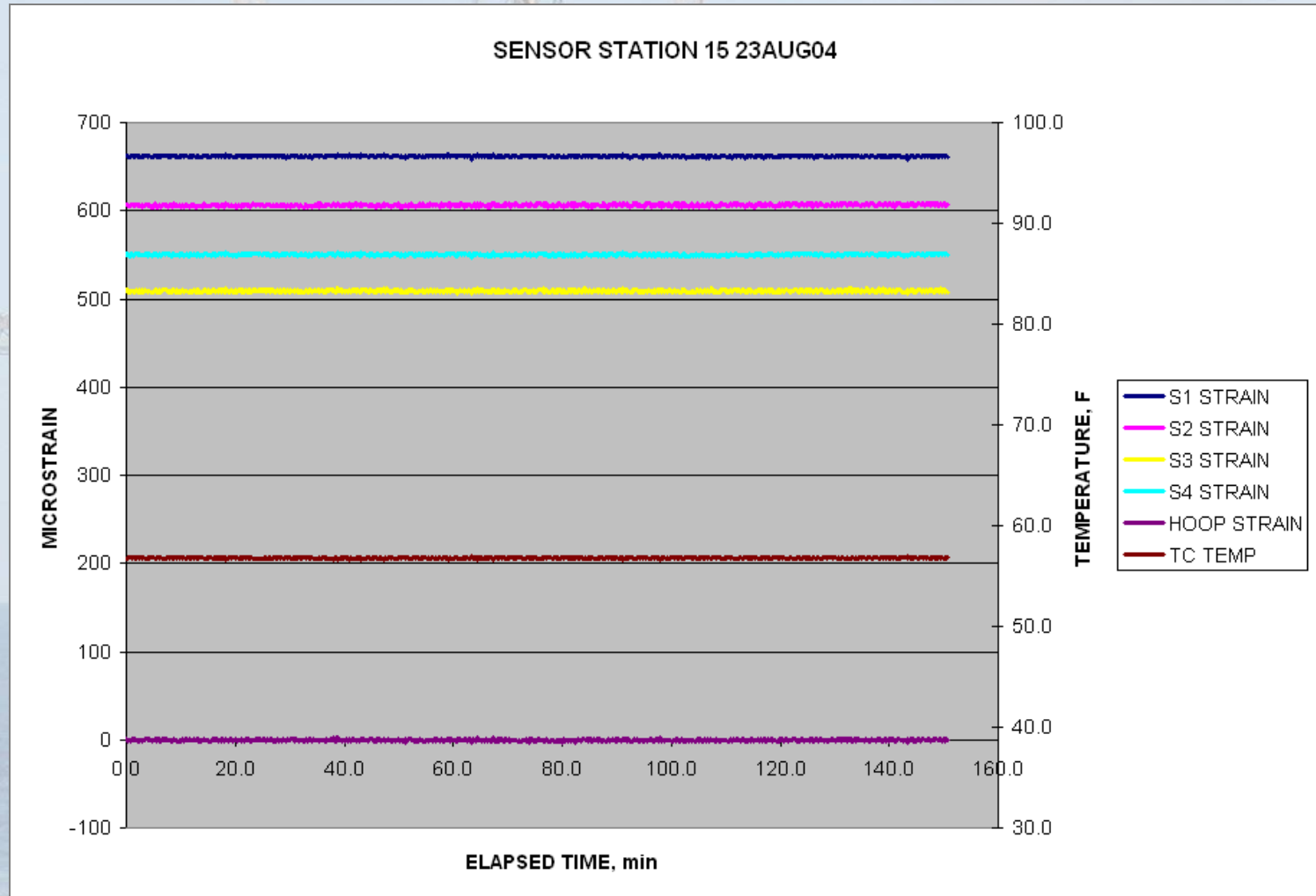
Riser Monitoring System

- Deepwater Installation

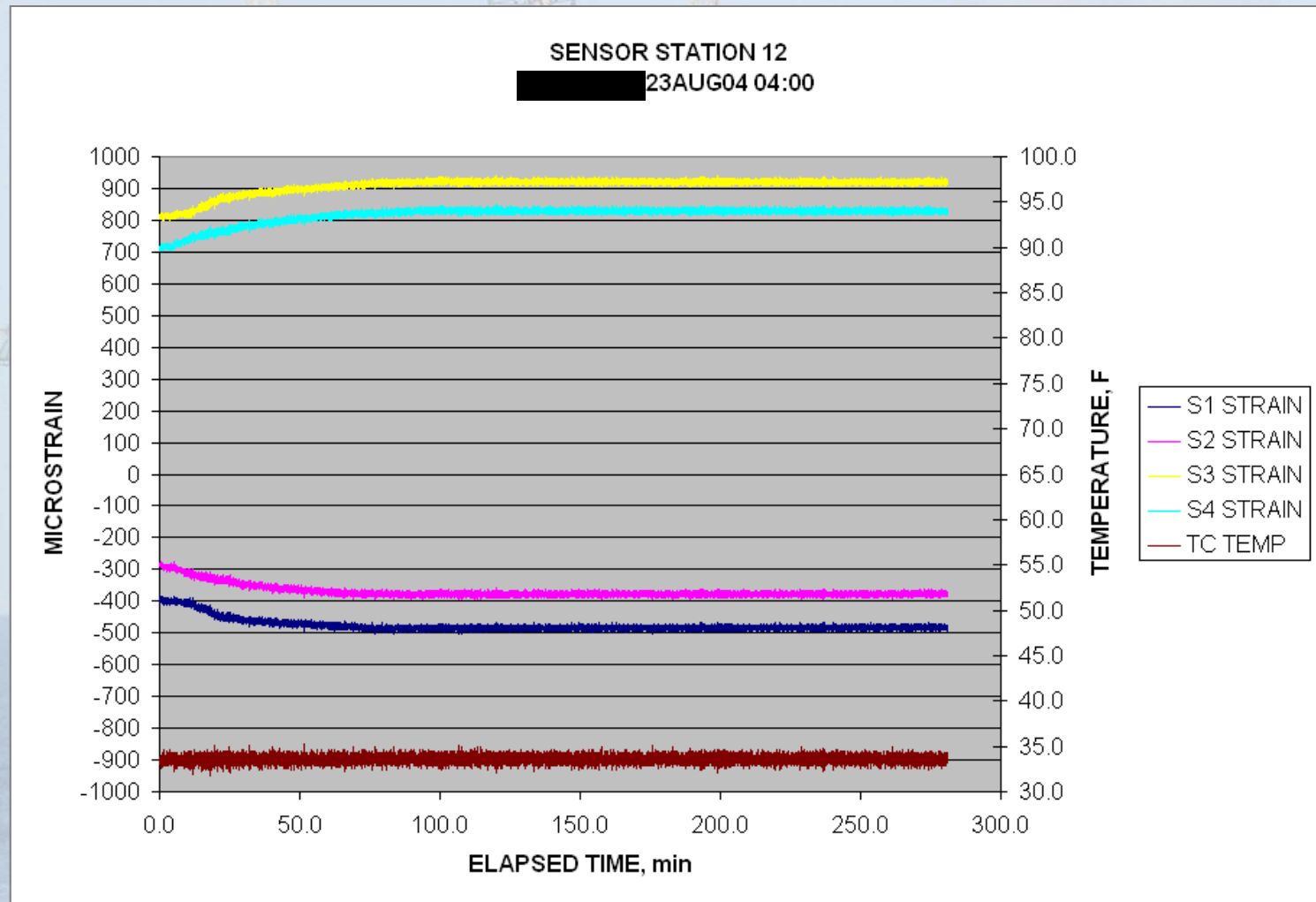


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39.55

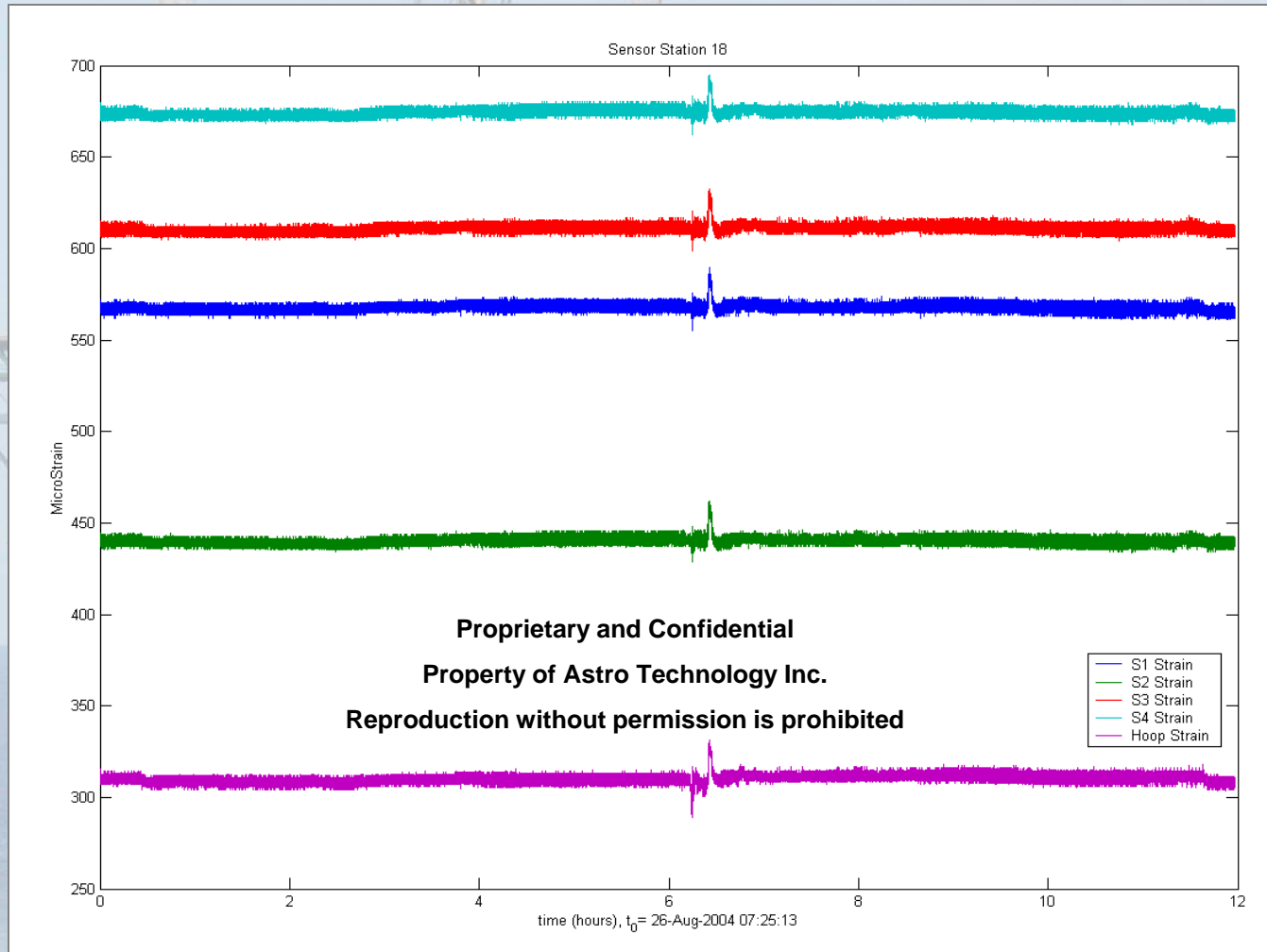
Deepwater Data – Steady State



Deepwater Data – Chain Jacks Moving Platform



Deepwater Data – Flushing Pig Passage



Riser Monitoring System

- Clamshell Qualification Testing

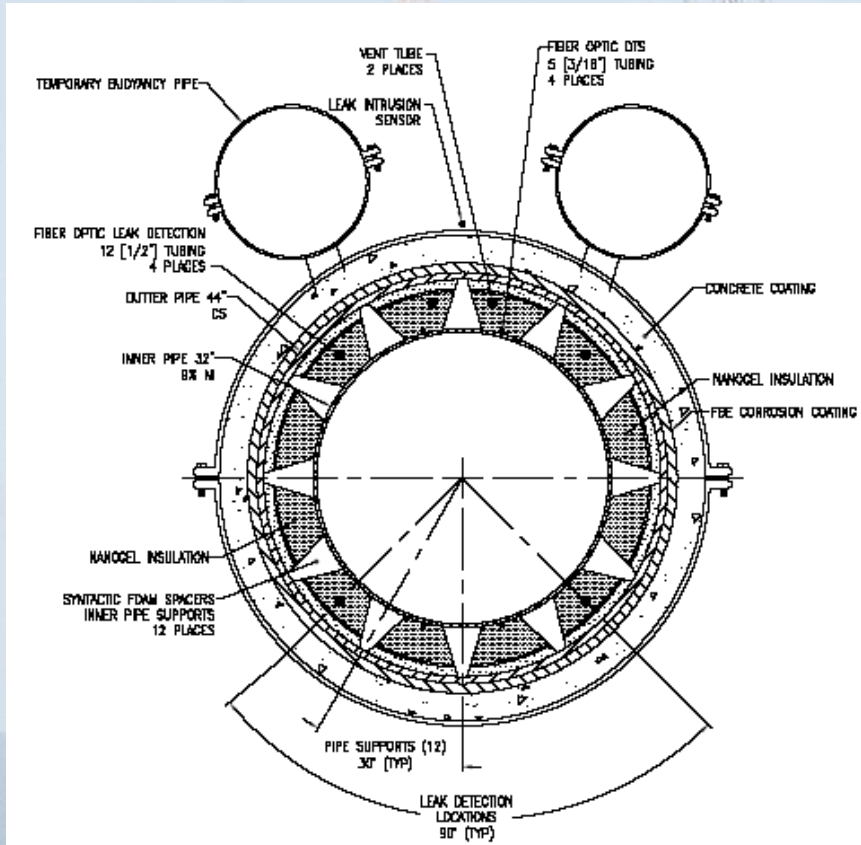


Riser Monitoring System

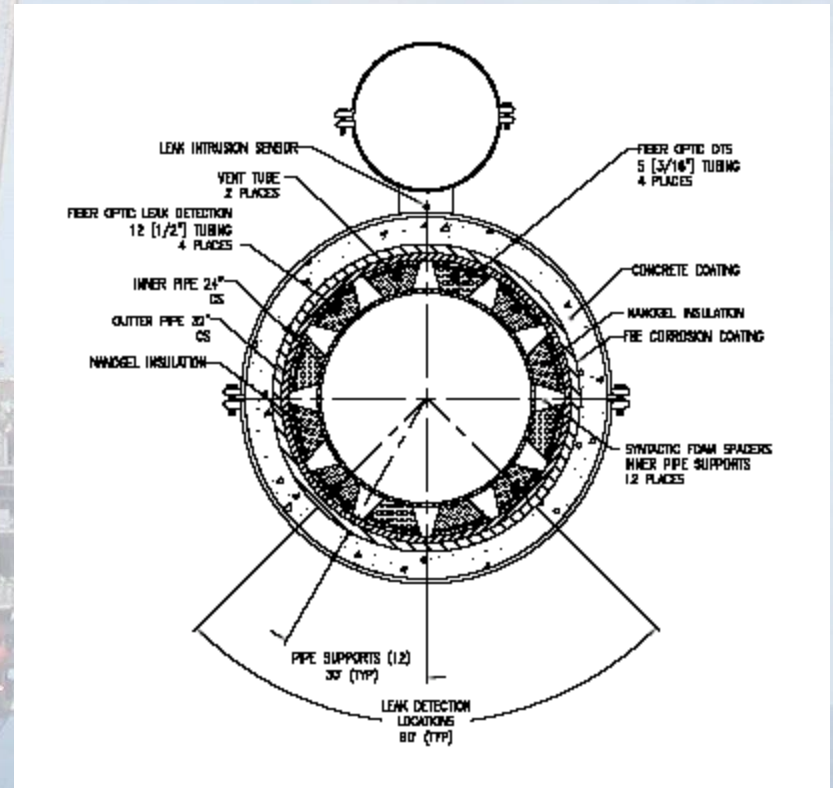
- Sensor Station Installation



LNG SENSOR LAYOUT

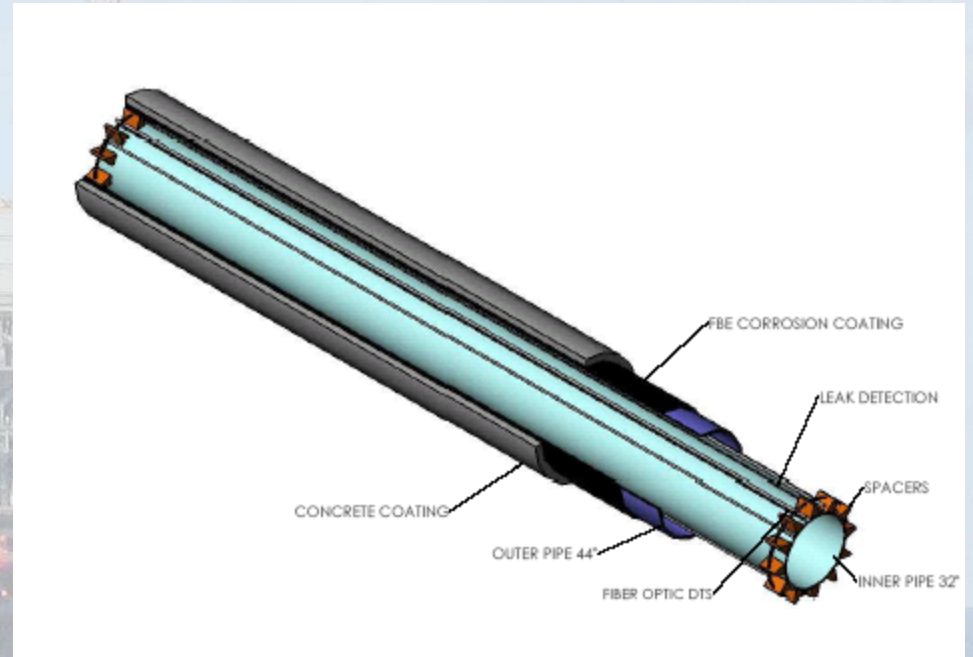
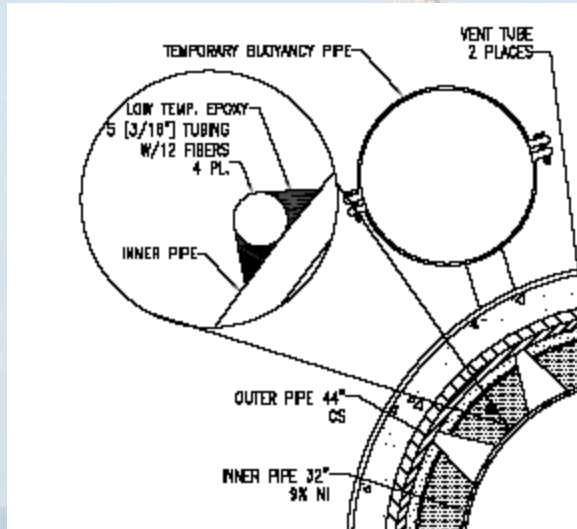


LNG

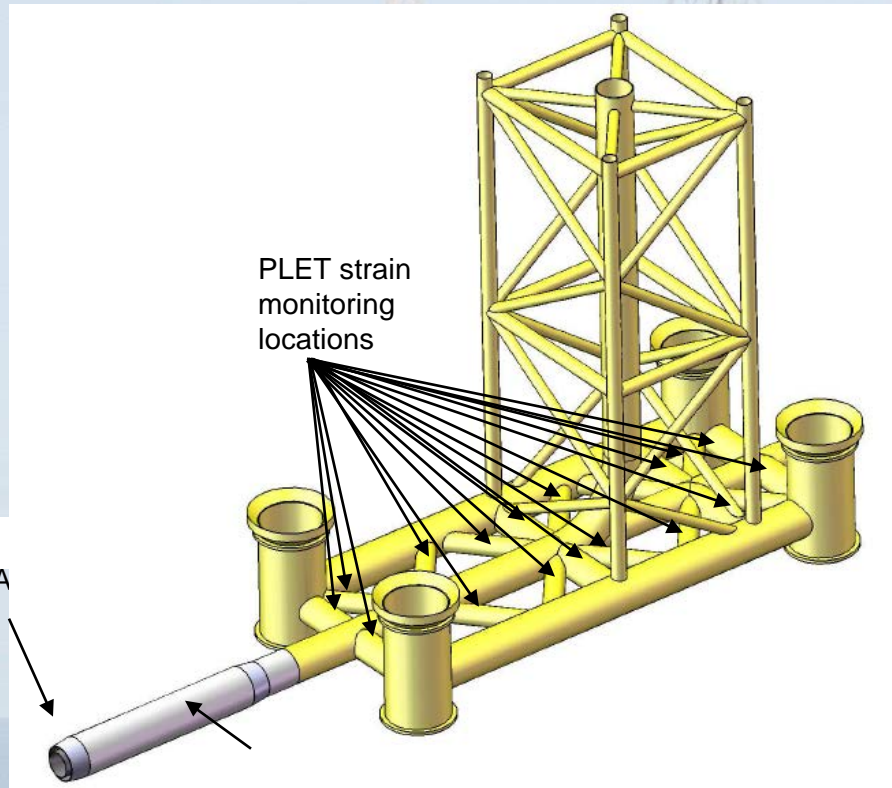


Multi Product

LNG SENSOR LAYOUT

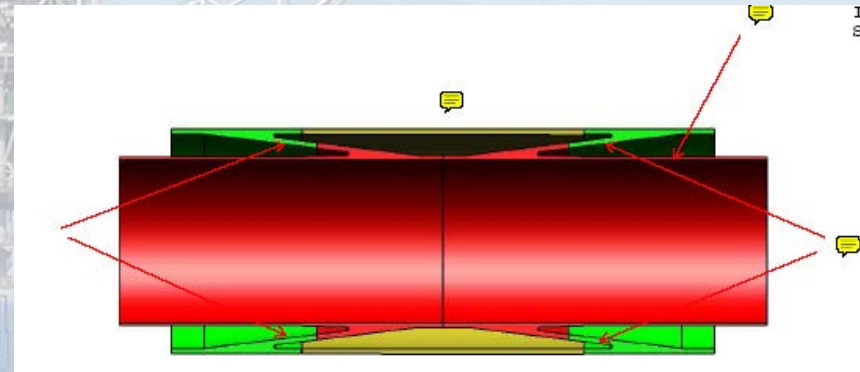


SENSOR LAYOUT



Bulkhead

PLET
STRUCTURAL
MONITORING



BULKHEAD
MONITORING

Cabling, Splicing and Connectors

FOBA Examples

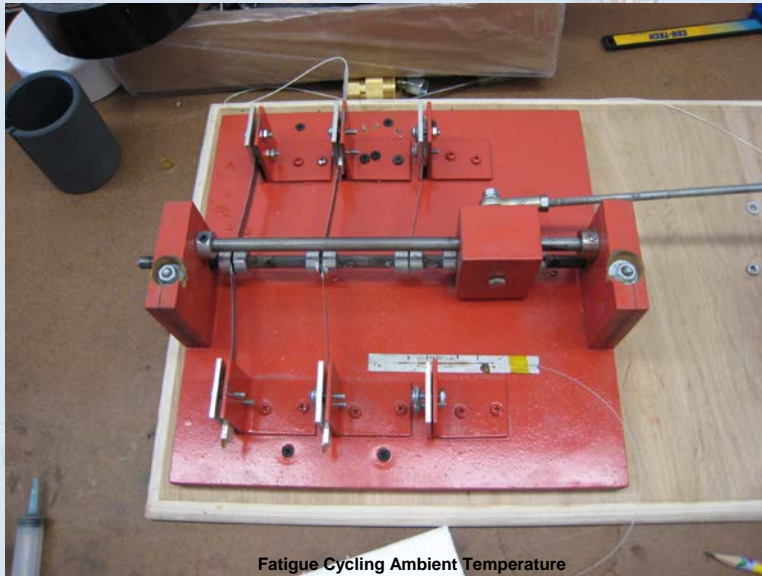


PLET Instrumentation

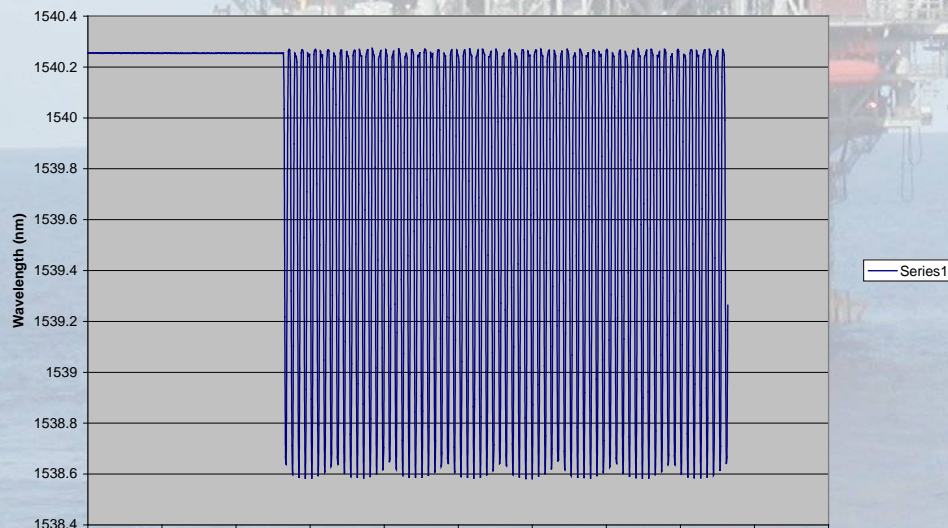


Subscale Test Summary

CYCLIC TEST



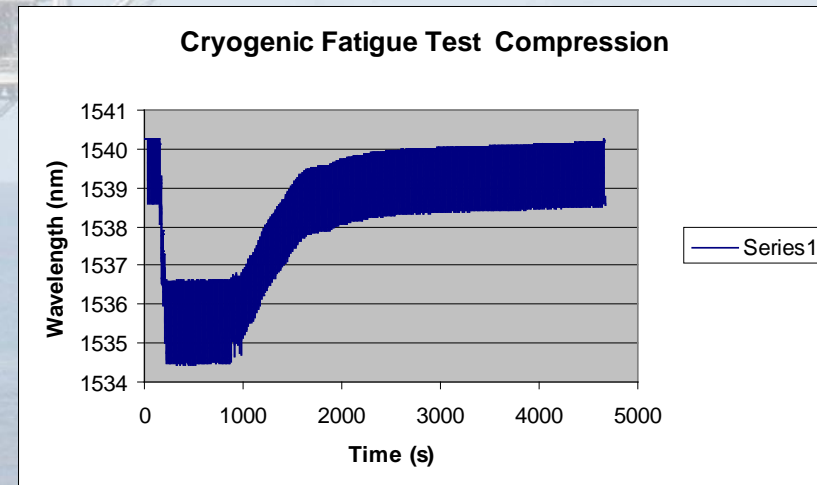
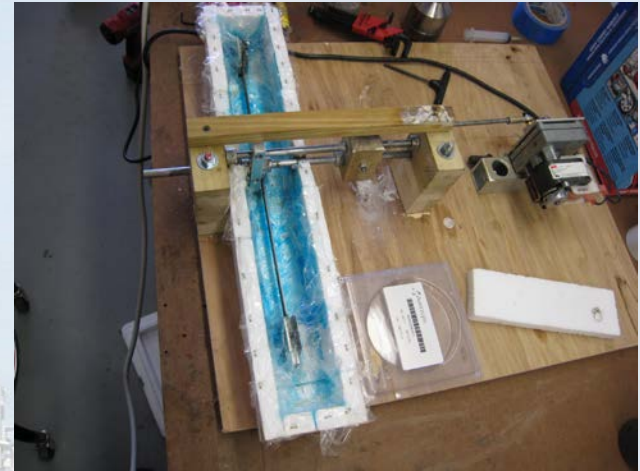
- Ambient temperature
- One million cycles
- One hertz
- ~1100 microstrain
- No degradation in adhesive/bonding observed



Subscale Test Summary

CYCLIC TEST

- LN2 temperature
 - -192 deg C
- 50,000 cycles
- ~1100 microstrain
- One hertz
- No degradation in adhesive/bonding observed



CRYOGENIC LEAK TEST

Fast response time

Detect leak in 2 seconds

Identify location of leak in ~ 2 minutes



Hydrate Blockage

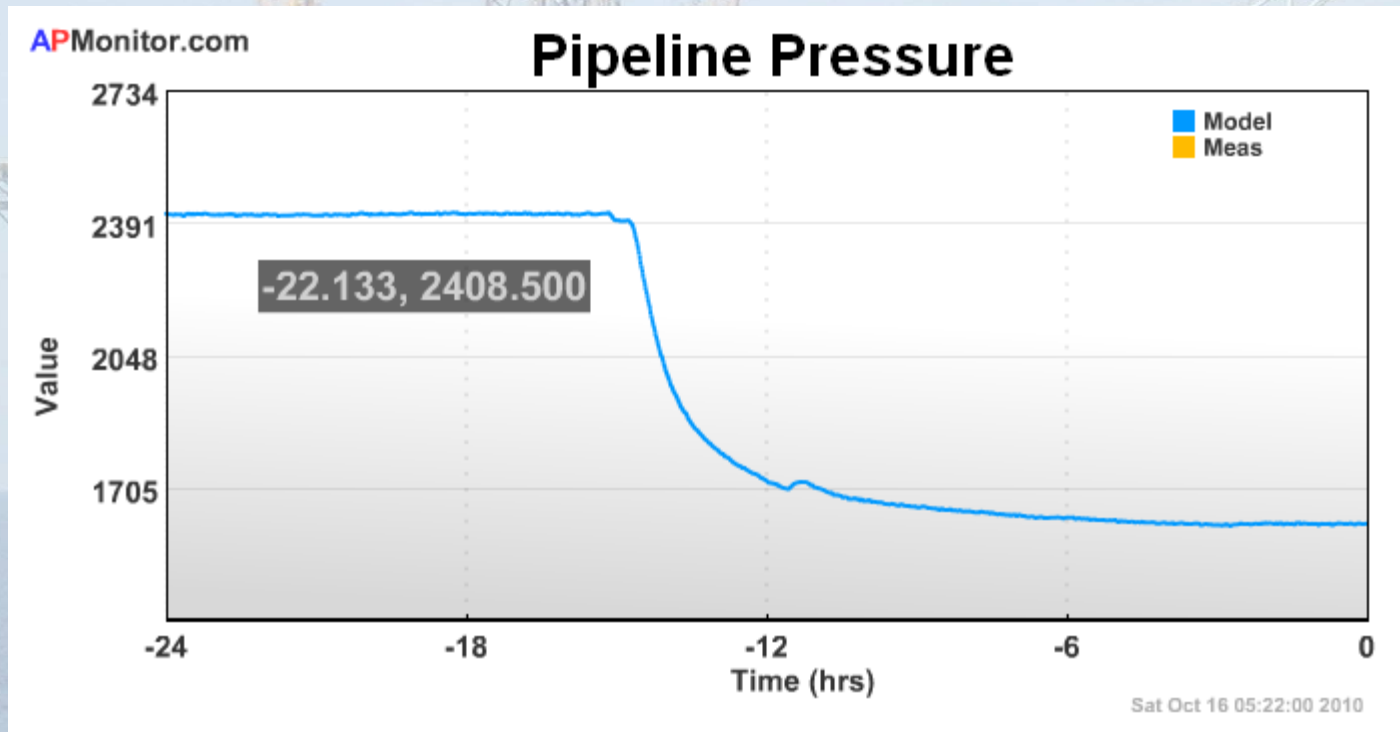
- Advanced method developed to scan pipeline and detect blockage
 - Relative amount
 - Location
 - ROV deployable
- Subscale demonstration
 - Successfully demonstrated blockage in 8 inch pipelines
 - Transducers in development for deepwater application

Software – Process Monitoring

- Fully utilize existing measurements
 - Hundreds of isolated measurements
 - Advanced Monitoring places data in context (as opposed to raw data)
 - Holistic view of available measurements
- Provides Smart Notifications
 - Early leak detection
 - Identify leak location
 - Reduction of unplanned shutdowns due to false alarms
 - Abnormal situation management

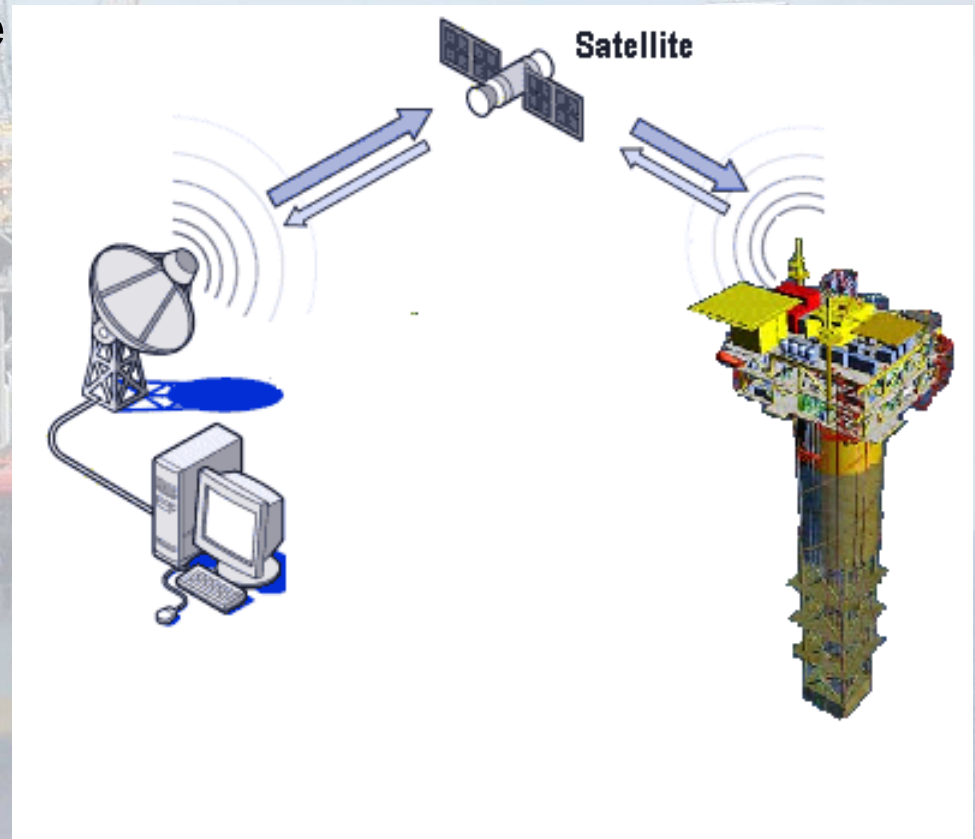
Deepwater Monitoring Software

Connect to live systems
Web accessible configuration and results



Monitoring from Remote Locations

- Remote display of real-time data
- Secure & encrypted data transmission
- Getting the right data to the make the right decisions



Remote Access to Pipeline Data



FLMT #2 (18 miles)

T 58.14 °F

[Temperature \(°F\) last 24 hrs](#)

[Temperature \(°F\) last month](#)

P 1616.97 psig

[Pressure \(psig\) last 24 hrs](#)

[Pressure \(psig\) last month](#)

FLMT #1 (36 miles)

T 34.95 °F

[Temperature \(°F\) last 24 hrs](#)

[Temperature \(°F\) last month](#)

P 2141.77 psig

[Pressure \(psig\) last 24 hrs](#)

[Pressure \(psig\) last month](#)

FLET (57 miles)

T 23.36 °F

[Temperature \(°F\) last 24 hrs](#)

[Temperature \(°F\) last month](#)

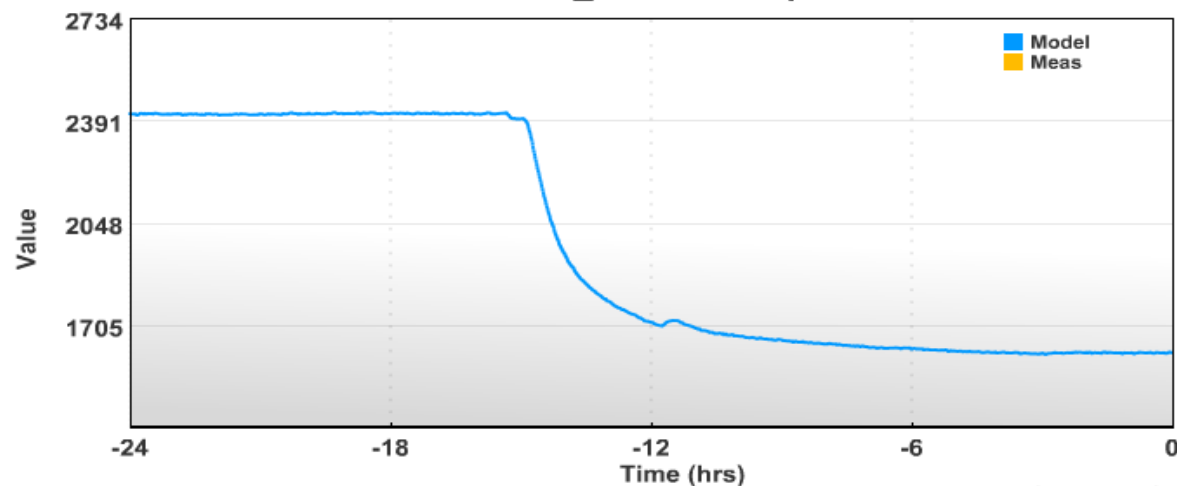
P 2404.17 psig

[Pressure \(psig\) last 24 hrs](#)

[Pressure \(psig\) last month](#)

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Software Benefits

Trident Subsea Systems

- Meet regulatory reporting requirements
- Flow assurance of oil and gas transport pipelines
- Structural characterization
- Visualize data from remote locations
- Reduce alarms by consolidating relevant information
- Improved design and operations
- Improved safety and environmental criteria